National Park Service
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Natural Resource Stewardship and Science

Invasive Species Management in Glacier Bay National Park & Preserve

2011 Summary Report

Natural Resource Data Series NPS/GLBA/NRDS—2011/221

ON THE COVER
View of cruise ship facing Margerie Glacier in Tarr Inlet in the West Arm of Glacier Bay. A collection bag of common dandelions resides among the dwarf fireweed in the foreground.
Photograph by: J. Robert Fisk, NPS

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J. Robert Fisk

National Park Service
Glacier Bay National Park & Preserve
P.O. Box 140
Gustavus, AK 99826

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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Acronyms

ADF&G	Alaska Department of Fish and Game
AKDNR	Alaska Division of Natural Resources
BCDA	Bartlett Cove Developed Area
EPMT	Exotic Plant Management Team
GIS	Geographic Information System
GLBA	Glacier Bay National Park and Preserve
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
NPS	National Park Service
NRCS	Natural Resource Conservation Service
SAGA	Southeast Alaska Guidance Association
SCA	Student Conservation Association
UNESCO	United Nations Educational, Scientific and Cultural Organization

Introduction

Glacier Bay National Park and Preserve (GLBA) encompasses 3.28 million acres of Southeast Alaska, west of the state capital, Juneau. GLBA, part of one of the largest UNESCO World Heritage Sites, is a unique mix of expansive mountain ranges, ice fields, calving tidewater glaciers, deep fjords, and many terrestrial landscapes. The many landforms within the park allow for a wealth of plant species from differing ecosystems, nearly unrivaled in any one geographical area of the world. Glacier Bay is host to lowland, old-growth forests, bogs and wetlands, as well as alpine tundra. The amount of shoreline within Glacier Bay also brings with it an abundance of tidally influenced ecosystems such as beach meadows, salt marshes, and estuaries. On top of it all, rapid glacial recession has exposed Glacier Bay over the last 250 years, quite literally to bare rock throughout the bay. With such dynamic glacial histories, not to mention the impacts that isostatic rebound and climate change have and will continue to have on ecosystem processes, GLBA exemplifies the many fluctuations and geologic formations that are possible; all of which elicit associated responses of plant successional stages.

The introductions of non-native, invasive plant species, which thrive in disturbed areas, are not strictly isolated to areas subject to heavy human impact. Disturbances caused by glacial recession are natural and common in Glacier Bay. The vectors for invasive species, such as backcountry camping and boating, in combination with any type of disturbance, natural or man-made, may lead to the establishment of invasive species.

While Glacier Bay may be continually more susceptible to invasive plant invasion due to regular natural disturbances, there are factors that prevent it from being a highly probable location for such invasions. First, Glacier Bay is relatively isolated from human introduced corridors. Glacier Bay is not a part of the state or federal road system, which may be the most important corridor for invasive plant colonization aside from intentional plantings of non-native species. Secondly, the vast majority of the park's visitors are cruise ship passengers who stay aboard the ships while inside the park. While this is a positive aspect to invasive species control, it is not reasonable to expect visitors to stay on board cruise ships and charter vessels at all times when visiting the park. On-the-ground visitor use is expected to increase in the coming years, meaning more kayakers and backcountry camping where natural disturbance is common.

State ferry service also began serving Gustavus, GLBA's gateway community, in 2010 and will increase in frequency starting in 2012, bringing more and more vehicles from larger, more heavily infested cities like Juneau. These factors will increase the probability that invasive species will be introduced into Gustavus and Bartlett Cove. As a result, the likelihood of introduction of new species to wilderness backcountry locations will increase.

The Alaska Exotic Plant Management Team (EPMT) in GLBA works to prevent the introduction and spread of invasive plant species into the park and to monitor the presence of invasive animal species as well. In past years, control efforts were limited to manual removal of invasive species. In 2011 the use of herbicides was incorporated into the available options for control in limited and reasonable situations.

The Alaska EPMT program was started prior to the most threatening invasive species becoming established beyond viable controls being effective. Thus far, most of the invasive species found

in GLBA are located in the Bartlett Cove Developed Area (BCDA), an area within one mile of all Bartlett Cove facilities. Only the common dandelion (*Taraxacum officinale* ssp. *officinale*) has successfully established in much of the backcountry of Glacier Bay. A focus in 2011 and in future years will be to increase monitoring of infestations in the most isolated and recently deglaciated locations in the Park and enhance the control efforts in those areas.

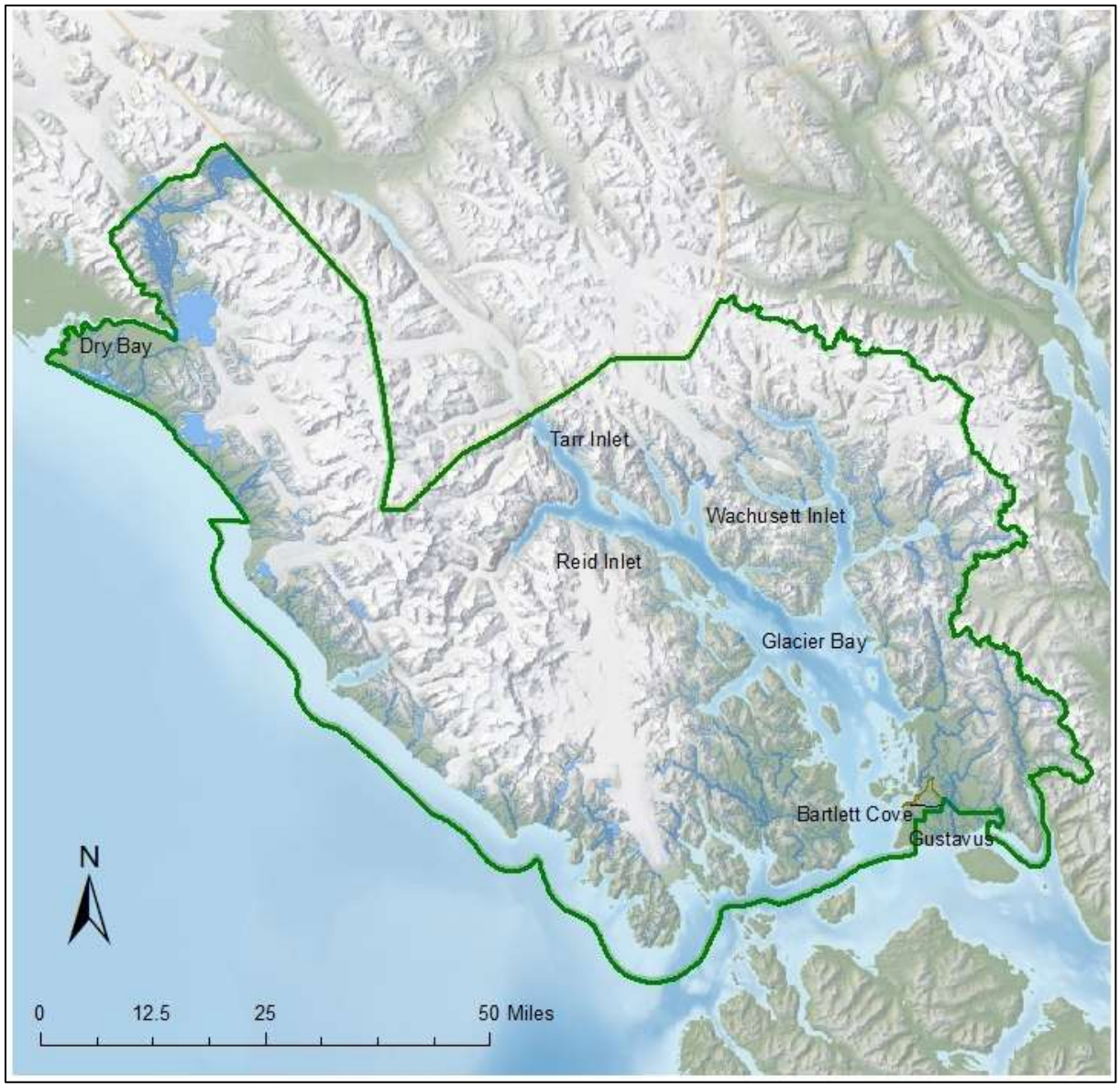

Figure 1. Glacier Bay National Park and Preserve boundary with noted points of interest.

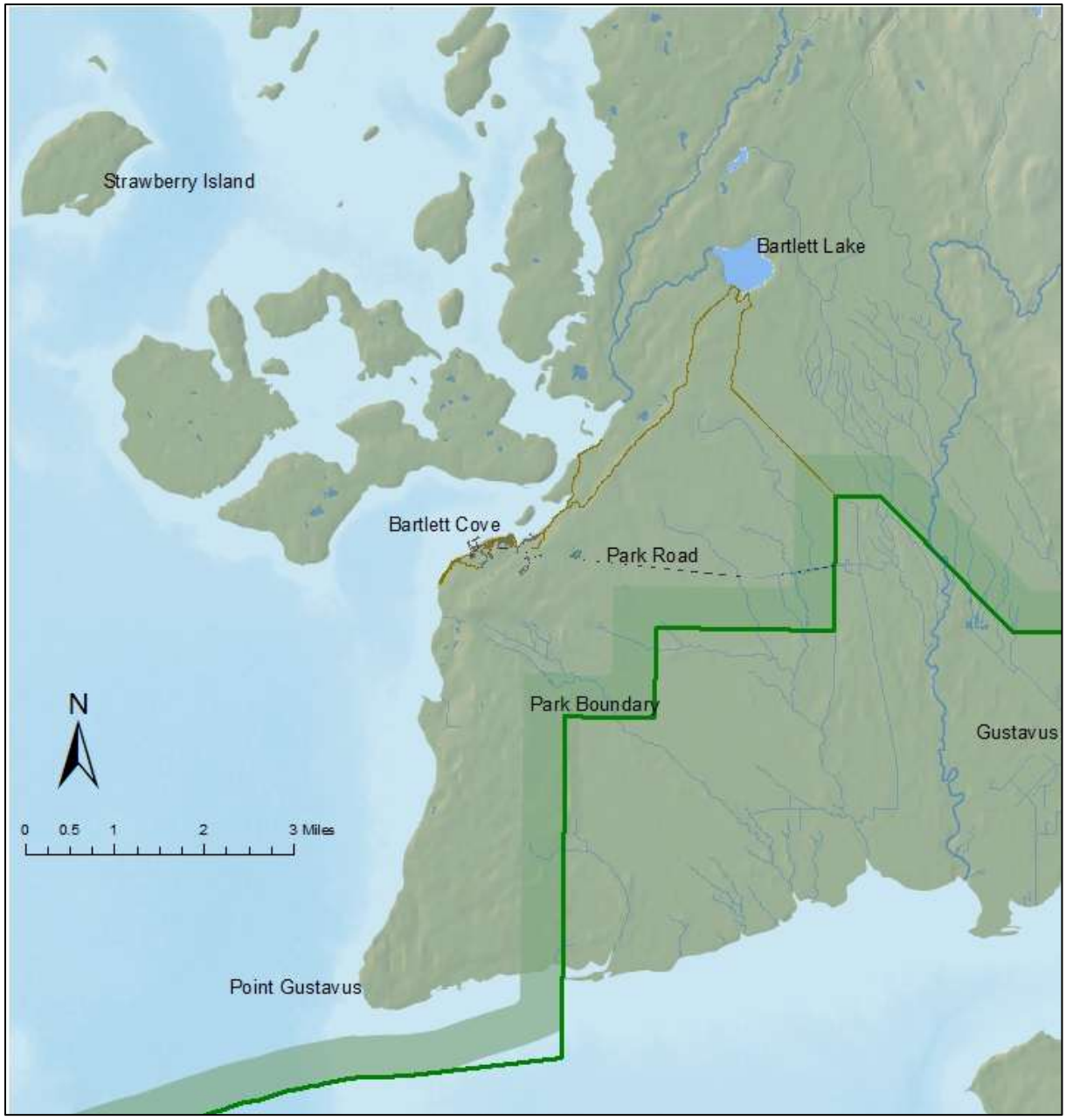

Figure 2. Bartlett Cove area and trails with noted points of interest.

Methods

Field work for the 2011 season was conducted from late May to mid-September. The GLBA EPMT consisted of one National Park Service (NPS) seasonal biological science technician, Robert Fisk, and, until the middle of August, one Student Conservation Association (SCA) intern, Shelby Timm. A Southeast Alaska Guidance Association (SAGA) AmeriCorps Youth Corps crew consisting of five crewmembers and two crew leaders assisted in invasive species control for two weeks in July. Data collection and management were conducted following the standardized 2011 Alaska EPMT Field Protocol (Million and Rapp 2011). Data were collected using a Trimble GeoXH 6000 Global Navigation Satellite System (GNSS) datalogger with TerraSync v5.10 software. Data were differentially corrected and edited using GPS Pathfinder Office v5.1. Data were then uploaded to the Alaska regional folder for processing by the regional EPMT staff. Data are then available for use in the geographical information system (GIS) database ESRI ArcMap 10.0.

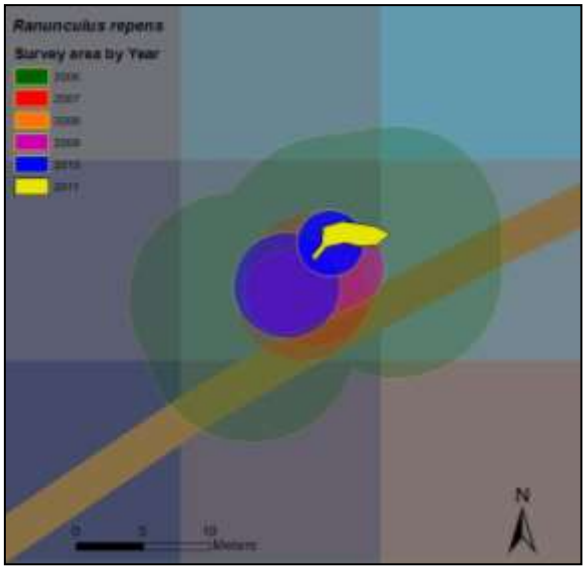

Figure 3. The distribution of a treated infestation of creeping buttercup (*R. repens*) along the Bartlett Cove beach trail over a six year period.

Accuracy in the determination of treatment areas increased significantly this season because of the use of the Trimble GeoXH 6000 GNSS datalogger. The addition of the Floodlight technology has improved the Trimble devices' accuracy to decimeter-level measurements, whereas older device accuracies were often recorded in submeter measurements, though sometimes one meter or more. For this reason, smaller areas that were previously mapped using line or point features with an estimated buffer area now can be effectively mapped using the polygon feature, making infestation size data more comparable from year to year (Figure 3). The level of estimation that goes into determining buffer sizes can vary significantly from person to person. By limiting the number of line and point features, estimation errors are reduced.

Data were collected from sites previously surveyed and/or treated, as well as sites never previously surveyed by the EPMT program. Information such as a site description, species present, percent coverage, disturbance type, control effort necessary for treatment, and percent treated, was standardized using the Alaska EPMT data dictionary referenced in the 2011 Alaska EPMT Field Protocol.

The majority of the plant material was removed, weighed, and dried in mesh bags in the exhaust room of the park's generator building. Dried plant material was then burned in the park incinerator at the waste management facility in Bartlett Cove. Some plant material remained on site due to logistical issues with backcountry travel. In cases of invasive species control in backcountry areas where travel was difficult, removed plant material weights were estimated.

Site Selection

Areas for control were determined by the invasiveness of the species, the resources available to control it now and in the future, and the potential for eradication. The Alaska non-native plant invasiveness rankings were used to help in determining the invasiveness of certain species (Carlson et al. 2008). The rank, from one to one hundred (higher numbers being more invasive), gives insight into a species' relative 'invasiveness' or threat to native plant communities in Alaska ecosystems. A species rank was weighed with the size of the infestations and this information was then weighed with the other species and infestations present in Glacier Bay, and determinations were made relative to each other as to how to proceed. Areas were then prioritized accordingly, often based upon phenology.

Figure 4. A SAGA crew and GLBA EPMT crew members pull tall buttercup (*Ranunculus acris*) near the main dock in Bartlett Cove.

New inventory sites were determined using previous Alaska EPMT GIS data, an area's historical and current use, and its overall potential for invasive species establishment. Accessibility to sites can be an issue for the GLBA EPMT so site monitoring is dependent upon the availability of transportation. As such, site prioritization may be altered to take advantage of transportation opportunities that may arise.

Control work was focused on the Bartlett Cove area for much of the 2011 season (Figure 4). The EPMT crew spent a week at Dry Bay in the Glacier Bay National Preserve at the end of July for monitoring and control. Some manual treatment was conducted in the wilderness areas of Glacier Bay as well.

Two herbicide applications were scheduled for completion in 2011. However, only a single application was performed due to weather complications during the scheduled treatment. The perennial sowthistle (*Sonchus arvensis*) infestation on Strawberry Island only received a containment treatment. The other target infestation, reed canarygrass (*Phalaris arundinacea*) on the west-facing hillside by the maintenance facility, did not receive treatment. Both sites will be scheduled for treatment in 2012 and likely limited follow-up applications in subsequent years as well to ensure complete eradication.

Results

Overview

Much of the past Glacier Bay wilderness monitoring and inventory data has not recorded the presence of invasive species. In 2011 the GLBA EPMT allocated a significant amount of time to monitoring common dandelion infestations in wilderness areas. The purpose of this was to obtain a better understanding of the extent and overall spread of common dandelions in the upper portions of the bay. The focus of these surveys was to determine whether control efforts would be warranted in coming years and where would be the most effective starting point.

While hand-pulling of common dandelions in the BCDA was done extensively in the past, controlling this species was all but stopped in 2011. It was determined that common dandelion is too widespread throughout the Bartlett Cove area, making treatment ineffective.

For a third straight year, oxeye daisy (*Leucanthemum vulgare*) was not detected at the Reid Inlet site which had been previously treated until 2008. It is now considered eradicated from the area.

A single plant of an unidentified species was found in Bartlett Cove this season. The specimen, a large, yellow-rayed composite thought to be in the *Senecio* genus, was pressed and mounted for the park herbarium collection.

Previously unidentified infestations of creeping buttercup (*Ranunculus repens*) were found this year. One, behind the park's fuel station, was found while treating an infestation of reed canarygrass. Another was found across the parking area from the GBQ03 permanent housing unit. Both of these infestations were manually treated.

Overall, 74.5 acres were inventoried in GLBA in 2011. Treatment was performed on 24.9 canopy acres, with 2.7 acres being the actual area treated for invasive species, taking into account the percent cover of the infestation as well as the percentage of the area treated. Approximately 1,700 pounds of wet plant material were removed.

Bartlett Cove

The BCDA is the main area for invasive species introduction into GLBA. As in past years, control efforts in 2011 were effective in limiting the spread of invasive plants. A re-evaluation of the effectiveness of manual control in the context of resources available and relative "invasiveness" allowed the EPMT to devote significant time to controlling creeping buttercup and to increase monitoring and control of reed canarygrass. These two species are currently the greatest threats within GLBA. Other species within the BCDA were also treated this season, including common timothy (*Phleum pratense*), quackgrass (*Elymus repens*), tall buttercup (*Ranunculus acris*), orchardgrass (*Dactylis glomerata*), oxeye daisy, herb Robert (*Geranium robertianum*), lady's mantle (*Alchemilla monticola*), perennial cornflower (*Centaurea montana*), pineapple weed (*Matricaria discoidea*), true forget-me-not (*Myosotis scorpioides*), sheep sorrel (*Rumex acetosella*), and common comfrey (*Symphytum officinale*). Time was devoted to all of these species within Bartlett Cove.

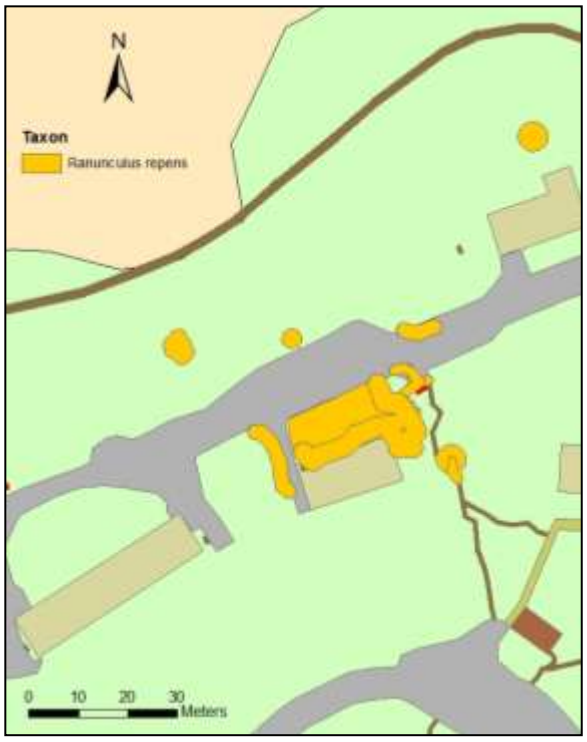

Figure 5. *R. repens* spreading from lawn in permanent housing in Bartlett Cove.

Creeping buttercup treatments were continued this season. The SAGA Youth Corps crew spent approximately 150 person-hours treating this species in Bartlett Cove. Additional time was spent controlling creeping buttercup by the EPMT crew as well. To be effective, manual control of *R. repens* must be a deliberately slow process. According to Densmore et al., using hand-pulling methods for treatment must be effective in removing all rooted branch nodes (2001). In fact, herbicide is the recommended method of treatment for *R. repens* (AKEPIC 2005). As a result, manual treatments in GLBA have been only moderately effective thus far. However, early evidence shows that some infestations' overall size has been reduced over time with yearly or multiple treatments per year. There are five areas of significant size where creeping buttercup is found in the BCDA. The largest site is an area in permanent housing around GBQ03. The infestation has spread from the lawn of the residence out across the parking lot to multiple naturalized areas (Figure 5).

Reed canarygrass was monitored and treated throughout the BCDA (Figure 6). New locations as well as previously identified areas were inventoried and treated. In some instances infestations were proven to have been previously misidentified. Discrepancies in data were accounted for and corrected in 2011. The maintenance hillside was contaminated with *P. arundinacea* seed when fill was brought in following construction of the new maintenance building (Rapp 2008). The area was scheduled for herbicide treatment in mid-August. A four hour time window of dry weather is needed prior to and following an application for it to be effective. Unfortunately the timeframe allotted did not present an opportunity for herbicide application, resulting in the only practical treatment being the removal of the seed heads, which occurred in late August.

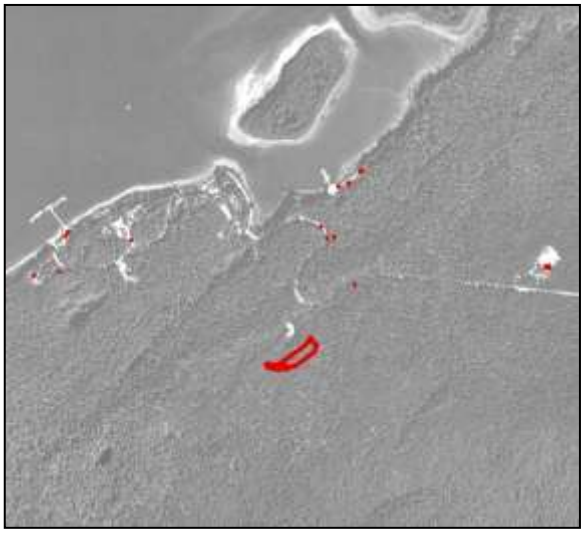

Figure 6. Distribution of reed canarygrass (*P. arundinacea*) in Bartlett Cove, 2011.

Many other invasive species are present on the maintenance facility hillside. A single Johnny-jump-up (*Viola tricolor*) plant was found and pulled in 2011, while in 2010 the number was less than ten. In addition, a number of perennial cornflower plants that have been found in past years

were removed. The other grass species that were found, common timothy and perennial ryegrass, were treated by the removal of the seed heads.

Several single oxeye daisy plants were found growing at random sites throughout BCDA in 2011. The water tower site has been the main focus of manual control for oxeye daisies in Bartlett Cove in previous years. As a result, the infestation has been significantly reduced in size over the past few years. Treatment in 2011 took approximately two person-hours overall to achieve 100% removal. Most of the individuals treated were seedlings. Another infestation exists in the lawn of permanent housing facility GBQ04. This site was manually treated multiple times for oxeye daisy as well as the only infestation of herb robert that exists in the park. The SAGA Youth Corps crew spent a few hours treating this location as both of these species can spread rapidly. Herb robert seedlings were observed growing in relative abundance in shaded areas of the property. Follow-up treatments were done to pull remaining and newly sprouted individuals. A non-native rose species (*Rosa* sp.) exists at this location as well. These shrubs were pruned to a few inches above the ground, and suckering stems were removed from the yard to prevent their spread.

Housing unit GBQ09 was host to a new species found in 2011. A single plant was located in the front lawn just outside the mowed area. Likely a garden escapee, this large yellow aster is thought to be in the *Senecio* genera, but further identification remains inconclusive. The specimen was added to the park herbarium for reference. Lady's mantle plants were identified and removed from the lawn area as well. These are also likely garden escapees growing beneath the eave drip line of the permanent housing unit. They were previously found in 2009 and were additionally located near the end of the driveway this season. A large perennial cornflower plant was also removed from that location.

An infestation of white deadnettle (*Lamium album*) has grown near the Glacier Bay Lodge since surveys were first conducted (Rapp 2005). 2011 was the first year that no plants were found, whereas only three stems were found in 2010 (Decker 2010). Also at the Lodge, true forget-me-not is growing in the parking lot island. It is possible that the area was purposely seeded with forget-me-not, or the seeds could have come from planter boxes by the Lodge steps. A similar native species, alpine forget-me-not (*Eritrichium nanum*) is the state flower of Alaska. Finding 'native wildflower seed' mixes for sale in Alaska is common, a potential source of this non-native look-alike. These mixes likely contain *M. scorpioides* seeds, due to it being a similar-looking species with the same common name as the native species and easier to cultivate. True forget-me-not is actually a European species often used in gardens as a groundcover for wet areas due to its tolerance to saturated soils (MBG 2011).

The waste management facility is host to a number of invasive plant species. Quackgrass is found growing in gravel inside the fenced area. Small patches of *P. arundinacea* were found here as well as *P. pratense*, *M. discoidea*, and a large infestation of *Ranunculus repens*. Common comfrey is found year after year in fill piles around the facility, the only known infestation in the park. All of these species were treated in 2011. Only a portion of the *M. discoidea* infestation was treated, as time allowed. A single European mountain-ash (*Sorbus aucuparia*) sapling was removed from the area within the creeping buttercup infestation as well. This species was last found in the park in 2007 in a similar location (Rapp 2008).

While the previous species are noteworthy but uncommon, a few non-native species are more common, if not abundant, within the BCDA, such as common dandelion, shepherd's purse (*Capsella bursa-pastoris*), mouse-ear chickweed (*Cerastium fontanum*), white clover (*Trifolium repens*), bluegrass (*Poa spp.*), and common plantain (*Plantago major*). These species are not considered a high priority for treatment, however, due to their low degree of invasiveness and relative abundance (Carlson et al. 2008).

Wilderness

Multiple trips were taken to wilderness areas of Glacier Bay in 2011. Potential visitor use areas were targeted as survey sites for invasive species presence. Generally, common dandelions are the only invasive species present in the northern portion of the bay. An infestation of oxeye daisy (*L. vulgare*) has been treated at Reid Inlet until 2008. No plants have been observed in that location since that time, and after three years this particular infestation can now be considered eradicated. Previous years' data were used to determine which sites had never been mapped for invasive species and which needed to be resurveyed. Due to the inherent difficulty that exists in travelling in wilderness areas around Glacier Bay, only a small portion of the park is able to be visited each year.

West Arm

Tarr Inlet in the West Arm was visited twice for monitoring and treatment. Common dandelion was found to exist in only one location, in a large area that faces Margerie Glacier. This location is a popular location heavily used by kayakers and overnight campers. Russell Island, just south of Tarr Inlet, serves as an overnight location for park researchers, GLBA protection staff and others, making it a likely location introduction point for common dandelions. In fact, common dandelions are present on the east side of the island near the protected cove where much of the camping occurs. The entire north end of Russell Island was surveyed, and no other common dandelion infestations were found.

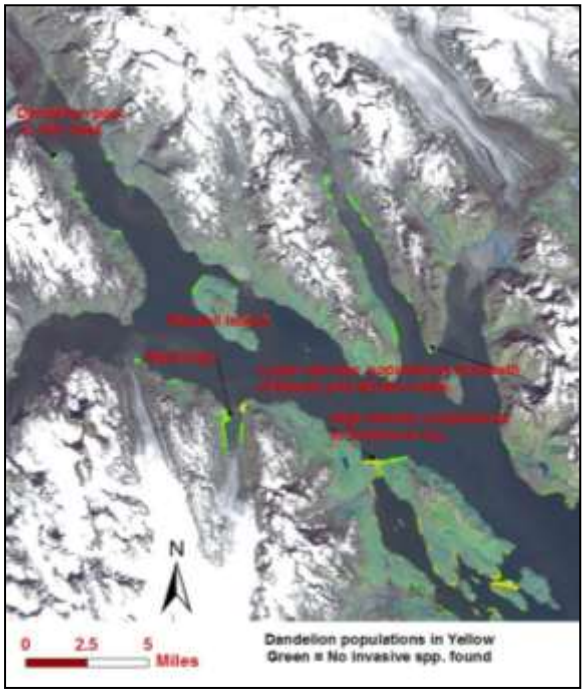

Figure 7. Survey sites in the West Arm with noted dandelion infestations.

As previously stated, it was determined that *L. vulgare* has been eradicated from Reid Inlet. Common dandelion infestations, on the other hand, in Reid Inlet are relatively common. Both the north and south shores of Reid Inlet were surveyed, with high densities of dandelions found at each. Wilderness camping is quite frequent in the area, a potential explanation for the existence and abundance of dandelions. These areas were the focus of surveys in the West Arm in 2011. Previous years' surveys covered a significant portion of the lower West Arm. These data were used to determine that surveys further up the bay are warranted for delineating common dandelion expansion (Figure 7).

Comparing 2006-2008 data to those from 2011 shows that common dandelion rate of expansion is slow in Dryas dwarf shrub, bare ground, and closed low shrub habitats. Additionally, closed tall alder and willow is commonly the adjacent plant cover class in beach habitats. Besides having greater nutrient levels in the soil, closed alder/willow also has a dense canopy, preventing sunlight penetration and thus hindering dandelion growth. Evidenced by the large root and plant sizes compared to the overall spread of the infestation, common dandelion likely requires multiple years of growth before flowering can occur in these nutrient-poor habitats.

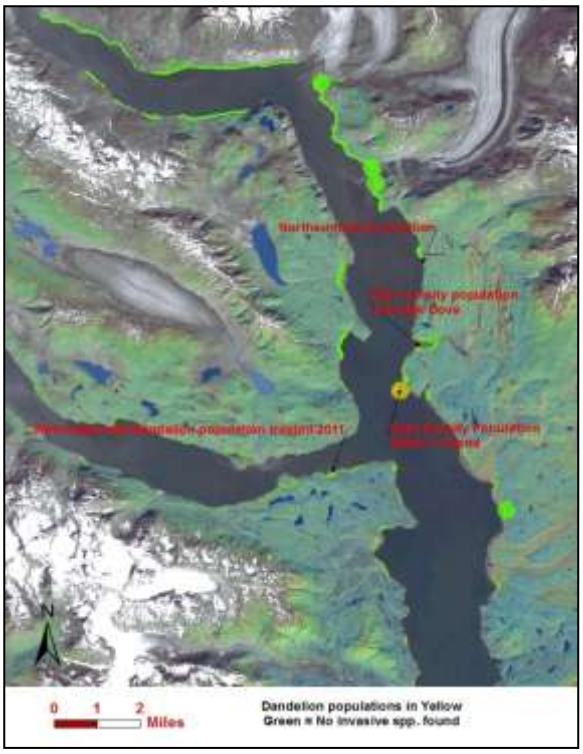

Figure 8. Survey sites in the East Arm with noted dandelion infestations.

Muir Inlet

One trip was made to Muir Inlet in 2011. Sites visited included those areas furthest up-bay where small infestations of common dandelions have been treated in the past. There are a few locations with high densities of common dandelions in Muir Inlet, including Sealer's Island and to the northeast in Nunatak Cove. The focus of the 2011 survey was Stump Cove on the west side of Muir Inlet as well as the south shore entrance to Wachusett Inlet. Small infestations of common dandelions were found and treated at both sites (Figure 8). An example of this is just south of Stump Cove where four common dandelion plants were found in 2007 and ten plants at that location in 2011. Surveys in 2010 showed that dandelions remain absent anywhere north of the south side of McBride Glacier.

Strawberry Island

Multiple visits were made to Strawberry Island in the Beardslee Islands in 2011. Perennial sowthistle exists in high densities on the south end of the island. This is the site of an old abandoned fox farm that existed from 1929 to 1938 (Kurtz 1995). It is likely that this large infestation is a remnant from that operation. An August herbicide application to treat the entire infestation was planned. However, as a result of complications with weather, approximately half of the infestation was treated in 2011. Milestone VM, a broadleaf herbicide with the active ingredient aminopyralid, was applied at the rate of 3oz. per 9 gallons of spray over 0.303 acres. A monitoring trip in mid-September determined that the treatment was fully successful (Figure 9). *S. arvensis* is a perennial species able to reproduce by root fragments, requiring a multi-year focus on the area to guarantee eradication (MN DNR 2011).

Figure 9. Area of 100% coverage of perennial sowthistle on Strawberry Island (left), prior to the August 2011 herbicide treatment. Same area after herbicide treatment (right) in September 2011.

Reed canarygrass had been found on Strawberry Island in past years. It had been treated via hand-pulling through 2009 when only a few stems were found and controlled (Rapp 2009). Due to misidentification in 2010, it cannot be determined whether *P. arundinacea* was present; however, no stems were found in 2011.

Dry Bay

The EPMT crew visited Dry Bay in Glacier Bay National Preserve in July of 2011. Invasive species are spreading from cabin sites as well as airstrips and the former fish plant site near the Dry Bay ranger station. Oxeye daisy is present at the fish plant airstrip as a result of fill that was brought in to replace contaminated fill that was removed in 2005 (J. Capra, pers. comm. August 2011). With help from the law enforcement rangers stationed in the preserve, the area was 100% treated for oxeye daisy following the visit by the EPMT crew. Other cabin sites were surveyed as well. A high density of oxeye daisy seedlings was found at the Hazen cabin site near the Dog Salmon airstrip (Figure 10). This site had been treated through 2009 with positive results. No monitoring was done in 2010; however the overall survey area had not increased since the last one in 2009. In 2011 the area was treated for flowering plants, but full seedling treatment was not possible due to time constraints.

Figure 10. Oxeye daisy seedlings at a cabin site in Dry Bay (left). SCA intern Amanda Wolfe holding a bouquet of daisies in Dry Bay (right).

In past years bigleaf lupine (*Lupinus polyphyllus*) has been extensively surveyed in the preserve. Surveys show that bigleaf lupine is quite common in the Dry Bay region outside the active floodplain of the Alsek River (Rapp 2009). Due to ambiguities surrounding the native range and natural range expansion of this species it was not prioritized for monitoring or control in 2011(Hultén 1968). The possibility that *L. polyphyllus* and *L. nootkatensis*, a native lupine, are hybridizing makes for an increasingly difficult scenario (Rapp 2009).

Gustavus

Gustavus is the gateway community to GLBA and is an important factor in the control of invasive species within Bartlett Cove. Monitoring for invasive species has been conducted for many years and was continued in 2011. With the encroachment of species such as reed canarygrass and oxeye daisy in Gustavus, the focus for 2011 was the main road leading into the park. Additionally, visitors arriving on the ferry with vehicles from Juneau with the potential to transport seeds of more harmful species are justification for increased monitoring along the road corridor.

Figure 11. SCA intern Shelby Timm in front of *L. tatarica* shrubs in Gustavus.

Gustavus is a small community that generally has a strong connection to the park. GLBA EPMT staff is often invited to observe and monitor private lands that potentially harbor invasive species. Visits were made on multiple occasions in 2011 to monitor private property in town. A previously undocumented species, Tatarian honeysuckle (*Lonicera tatarica*), was identified at a private residence where surveys have occurred in the past. *L. tatarica* has an Alaska invasiveness rank of 66 (Carlson et al. 2008). Three large shrubs, one over 1m and two greater than 2m tall, exist in this location (Figure 11); however, there is no evidence the plants are spreading, likely due to regular pruning and mowing in the area. The potential for seed dispersal does exist.

The volunteer SAGA crew spent two days controlling reed canarygrass, common comfrey, and European mountain-ash (*S. aucuparia*) around the park housing facilities in town. Species in Gustavus that are not present in the park include orange hawkweed (*Hieracium aurantiacum*), European mountain-ash (one sapling removed from the park in 2011), and bishop's goutweed (*Aegopodium podagraria*). Monitoring for these and other species has been ongoing and was continued in 2011.

Discussion

Bartlett Cove

The BCDA is highly impacted by human activity. Construction projects, brush and lawn mowing, heavy visitor use, and trail and roadside clearing are some of the larger impacts that are ongoing in Bartlett Cove. Many of these impacts have a negative effect on native vegetation. Altering or heavily impacting these natural areas increases the likelihood that exotic invasive species will become established. A main goal for GLBA is to provide enjoyment to visitors who come to experience Glacier Bay in its natural setting. Balancing natural processes with visitor safety and access, seemingly conflicting goals, is difficult. Nevertheless, thoughtful planning can make it possible to manage an area for visitor enjoyment while retaining its natural appearance.

The greatest challenge for invasive species control in Bartlett Cove is brush removal (mostly to enhance visibility for safety and facility maintenance purposes) that exposes areas to disturbance. Exposing the understory to direct sunlight – especially where the ground surface is disturbed and mineral soil is exposed – increases the possibility of invasive plant establishment. One example of this in Bartlett Cove is along the park road where roadside clearing is necessary to keep roads clear of brush and debris. Effort should be made to balance safety needs with the desire to keep as much native vegetation intact as possible. Doing so will help provide a natural setting for visitors to Glacier Bay as well as limiting the invasive plant pressures that are likely to increase along with the visitor use to the park.

Figure 12. SCA intern Shelby Timm standing among the alder regrowing along the maintenance facility hillside in June 2011. This alder was removed a couple weeks later.

Sites like the maintenance facility hillside, which is host to many invasive plants including the largest infestation of reed canarygrass in any Alaska's national park unit, is an example of how our actions can have a serious negative impact on native plant communities. Revegetating cleared sites with locally collected, weed-free seed mix should be mandatory for GLBA in the future, as resources become available. Subsequent clearing of alder shrubs on the hill has exacerbated the problem by promoting increased sunlight on an area of invasive grass, a perfect condition for the spread of that species (Figure 12).

A species spreading in Bartlett Cove, creeping buttercup (*R. repens*), will need a developed and focused plan for its control. *R. repens* has an average invasiveness rating of 54. However, the potential for eradication of this species makes it of high importance in GLBA. At least five relatively large infestations in Bartlett Cove have been found so far, in varying types of vegetated habitats. It is a tolerant species growing in full sunlight in gravel along the park road as well as a dense alder thicket in permanent housing. *R. repens* is reaching a critical point in its spread where in a few years, manual control may no longer be effective in reducing the size or number of infestations. Keeping creeping buttercup out of the wilderness areas is of considerable importance. Containment may be a valid control focus for the near-term. While manual treatment options may be a proper option for the next year or two to determine effectiveness, chemical control should be considered for the future management of this species. Using current data from

GLBA as well as published accounts of recommended treatment strategies, it is recommended to use manual control of small infestations (1-2 m²) and to contain large ones. Herbicide application is necessary for eradication of larger infestations. *R. repens* is a good candidate for herbicide application because it is one of the last herbaceous species to die back in the fall. In 2011, green plants were observed into late October while the majority of the other surrounding and taller species had died back. An herbicide treatment would likely be effective through September and potentially into October, and would have little, if any impact on surrounding native vegetation.

Priority areas like permanent housing building GBQ04, which has an infestation of oxeye daisy and the only infestation of herb Robert (*G. robertianum*) in the park, should be able to be made weed-free in the next few years with continuing manual treatments.

The waste management facility is an area where significant ground-layer disturbance occurs every season. Being the source of fill material for the park, regular monitoring of the area is instrumental in keeping weed sources from spreading to other areas of Bartlett Cove.

Every year reed canarygrass is found in new locations in the BCDA due to the large seed bank which exists outside the park. However, the areas where it has reappeared have been isolated and heavily treated (except for the infestation at the maintenance facility) and likely will be able to be eradicated with regular manual treatments. With a concerted effort, reed canarygrass can be contained and not allowed to spread to wilderness areas; with the upcoming herbicide treatment this species could be eradicated in the near future. The focus should be on the park road where open disturbed ground, combined with vehicle and pedestrian traffic transporting seeds into the park, provides ideal conditions for invasive species establishment. Better roadside vegetation management would have a big impact on the ability of this and other invasive species to become established.

A Vegetation Management Plan is being developed for GLBA and should be completed and signed by the 2012 season. In the Plan, issues such as roadside brushing, vegetation alteration for construction projects, and management of vegetated areas around park buildings are being addressed. Policies that protect natural vegetation will significantly reduce the potential for invasive plant infestation establishment in the park. Select current park actions have had a detrimental effect on native plant regeneration in many areas. Altering the park's current vegetation management strategies to take into account natural processes for revegetation, such as allowing for alder growth, will improve the ability for native species to be successful. Additionally, integrating NPS policies regarding what employees are able to plant in the park or what species concessionaire's staff is allowed to cultivate in ornamental planter boxes allows GLBA EPMT staff to focus on the many other invasive plant issues currently facing the park.

Restoration

A necessary component of invasive species management is a plan for native plant revegetation following a soil clearing project. When soil is disturbed without a plan for active revegetation, more time may be spent removing invasive species later than would have been spent on the initial revegetation effort. Exotic plant management should focus not only on removal of invasive plant species, but also those preventative actions that will significantly reduce the chances for invasive species establishment. A revegetation protocol is needed for the BCDA so that a program can be developed that promotes the health of native plant communities, making

for a natural developed area for visitors to enjoy. Such a protocol would address seed collection techniques, stratification, storage, and species diversity. Other opportunities exist for revegetation, including vegetation mat salvaging and establishment, and seedling production and planting. The NPS shares a Memorandum of Understanding with the National Resources Conservation Service (NRCS) for the "Mutual Development of Plant Materials for Revegetation". This agreement brings together the NPS, the NRCS and local Plant Materials Centers to work on revegetation projects in national parks. The agreement can be utilized to involve the Alaska Plant Materials Center in Palmer, AK in large-scale revegetation projects in GLBA in the future. While there may be limitations to what is currently possible for GLBA, the available resources, both material and knowledge-based, are invaluable.

Fill material from outside of the park is sometimes needed for construction projects in Bartlett Cove. Obtaining material from weed-free sites is critical to keeping newly-devegetated areas free of invasive weeds. The Alaska Department of Agriculture is currently working to develop a weed-free gravel program (AK DNR 2010). Once established, it could assist GLBA with accessing weed-free material that otherwise currently goes uninspected.

Wilderness

Common Dandelions

After years of manual treatment in the BCDA, common dandelion infestations have expanded or remained the same. However, dandelion infestations in the upper portions of the bay have not significantly expanded in the three to four years between surveys for many locations. This suggests that the rate of infestation growth in areas of less organic matter and lower nutrient levels, and/or more extreme environmental conditions generally is slow enough to warrant continued manual control efforts. Considering the fragility and uniqueness that these ecosystems represent, allowing natural plant successional processes to take place without the impact that invasive species may have on them is a valuable goal. In addition, it is still possible to take advantage of the opportunity to preserve wilderness areas in their native state in Glacier Bay. In areas with low levels of soil nutrients, the increased competition that dandelions bring to those limited resources may have a detrimental effect on early-successional plant communities.

Common dandelions were observed growing among the primary successional lichens and mosses in Tarr Inlet. Occasional individuals were observed growing in bare ground habitats as well, showing that nutrient requirements for *T. officinale* spp. *officinale* are relatively low. Nitrogen is produced primarily by *Dryas* sp. in these young soils and is sufficient for dandelion growth, made apparent by their presence in such areas (Chapin et al. 1994). According to Tilman et al., dandelion growth is limited by potassium concentrations in low-nutrient soils (1999). Due to the parent material being limestone, sandstone, and igneous glacial till, potassium is in relative abundance in Glacier Bay (Chapin et al. 1994).

With current data it is difficult to know at what rate dandelion infestations are able to spread in this type of substrate and climate. Knowing when the plants were first introduced is necessary for an accurate infestation growth rate assessment. It is possible that common dandelion infestations may grow at an increasing rate due to the increase in organic matter they produce. However, early data shows that the spread over a three-year period is relatively slow. Future data will be useful in observing new infestations and documenting existing ones over a longer time period. In

1935, Cooper documented *T. officinale ssp. officinale* at the edge of an alder thicket on the Gustavus forelands (1939). This is the earliest documented presence of dandelions in the area. Studies from a similar time period do not note the presence of dandelions in the northern portions of Glacier Bay.

Figure 13. SCA intern Shelby Timm holds a large dandelion taproot in Tarr Inlet.

Personal observations made in 2011 show that effective manual treatment is difficult for older, well established plants. Due to the rocky substrate, full taproot removal can be quite damaging to the soil layer. In the future, chemical treatments may need to be an option for the larger infestations, considering the disturbance that is created by removing plants in the more fragile vegetation such as *Dryas* sp. mats and mosses (Figure 13).

More monitoring is needed to determine to what extent wilderness backcountry dandelion control would be an effective use of resources. It is clear, however, that dandelions could be eradicated from the farthest reaches of the bay within a short period of time with efficient prioritization of the resources currently available. Differing strategies for control should be employed for the east and west arms of Glacier Bay due to the current extent of dandelions in each. In the East Arm, common dandelion infestations reach just over halfway up the arm into Muir Inlet, whereas West Arm infestations reach nearly to the glacial termini. Determinations on treatment areas should be based on infestation size, access (*ie.* in motorless waters during part of the visitor season), surrounding infestations, potential rate of growth, etc.

The common dandelion infestation in the West Arm facing Margerie Glacier could be eradicated in just a few years with regular treatment. A small percentage of this area was treated in 2011 after the plants had seeded. The infestations in Reid Inlet are significantly larger, making treatment and potential for eradication more difficult. Ibach Point and the Ibach cabin sites on either side of the mouth of Reid Inlet host relatively large, dense infestations of common dandelions. Both of these sites have been and will likely continue to be heavily used by kayakers and backcountry campers. Considering the size of the infestations as well as the heavy use of the area, it may be warranted to remove only flower heads for the short-term to eliminate the seed source, while focusing intensive efforts on smaller infestations that can be more easily eradicated. Once that is achieved, the Reid Inlet infestations could then be fully controlled. Working closely with the interpretive ranger staff at the Visitor Information Station in Bartlett Cove to recommend and guide visitors to certain camping locations may be a helpful tool in limiting the spread of common dandelions from these areas to others up-Bay. Letting campers know where the common dandelion infestations are before they go could allow them to plan for: a) avoiding those sites altogether; b) using only those sites, so as to not spread the seeds to other areas; or c) using the areas with dense infestations as the final stop on a backcountry trip.

Muir Inlet infestations have not been found north of Stump Cove on the western shore and approximately halfway between McBride Glacier and Nunatak Cove on the east. Increased monitoring north of these infestations should be a priority as well as control of those known infestations. Allowing dandelions to move up-Bay to McBride Glacier and further into Muir Inlet would be unfortunate knowing that it is preventable. Infestations south of Stump Cove and Nunatak Cove should be controlled as time allows. Sealer's Island has not been surveyed due to bird nesting restrictions from May to August. Sealer's Island is a small island with a significant infestation of common dandelion and a potential seed source for spread up-Bay. While more difficult, controlling the infestation outside of the access restriction dates could have a positive effect on common dandelion control.

Larger infestation's farther up-Bay such as Nunatak Cove in Muir Inlet and Reid Inlet in the West Arm are good candidates for volunteer group control because of their ability to cover larger areas more quickly. Focusing on more extensive infestations allows for more of their time being spent on control work versus travelling to and from smaller infestations. Travel time can be a limiting factor for invasive species work in Glacier Bay, so adequate organization and planning is important to being effective.

Other species

Monitoring for additional invasive species besides common dandelions should be a priority in all areas of Glacier Bay wilderness. Due to the relative size of the park, prioritizing areas for monitoring is critical for EPMT crews in the future. Commonly used backcountry camping areas are obvious sites for monitoring. The Reid Inlet oxeye daisy infestation shows that it is possible for other species to become established in relatively recently de-glaciated locations. Considering the current infestations of reed canarygrass in Bartlett Cove, it is possible it could easily spread to wilderness areas regularly used by backcountry visitors. A small infestation was found on Strawberry Island and treated prior to it becoming highly established. Well thought-out strategies for monitoring should be employed to prevent an area from going unchecked for many years. Visitor use surveys are a good tool for prioritization of monitoring locations. While some areas such as the park's outer coast are quite isolated and receive very few visitors, they should be considered for monitoring every few years because invasive species establishment is still possible via seed and plant part transport by animals such as bears and birds.

Small infestations of reed canarygrass were documented in two locations in Excursion Inlet in 2006. These infestations were not treated and have potentially spread since. Sites like these that are small but isolated are easily missed, emphasizing the need for planned rotational monitoring for areas that may not seem to be high priority for invasive species establishment.

Gustavus

Monitoring in Gustavus was conducted as time allowed in 2011. Previous surveys showed that there has been some moderate growth in oxeye daisy infestations in recent years. If infestations are allowed to increase, additional pressure will be put on future EPMT crews for control within the park in years to come. Outreach efforts in the future will focus on eradicating this species from areas near the park boundary as well as along roadsides and other areas where seed dispersal would increase the likelihood of seeds reaching the park.

Orange hawkweed (*H. aurantiacum*) was monitored and controlled in town in 2011. A small infestation exists at the private residence, the former Glacier Bay Natural Foods location. Although the infestation was removed, it is likely that additional individuals were missed due to the lack of an exhaustive survey. Also at this location are three large Tatarian honeysuckle (*L. tatarica*) shrubs, as previously mentioned. While no other individuals were observed growing in the vicinity, monitoring for this species should be heightened to determine whether these shrubs are the source of any naturally established plants. Honeysuckle fruits were observed during a visit in August, which means it is likely that the seeds have the potential to fully develop and be dispersed by birds or other means. Many non-native tree and shrub species are planted in Gustavus. Limiting the scope of their use by promoting the use of native species would reduce the chance that any of these non-native species with invasive qualities could become a threat to native plant communities.

Future monitoring in Gustavus should be a regular aspect of invasive plant management in GLBA. Gustavus is a small community removed from the state road system and thus has the ability to resist the establishment of highly invasive species. With the increase in ferry traffic in 2012, however, it is likely that species such as Bohemian knotweed (*Fallopia* x *bohemica*) which is present near the ferry terminal in Juneau will show up in Gustavus in the not-too-distant future. If a new invasive species does become established in Gustavus, the park's advantage of being relatively isolated from larger cities is lost.

Dry Bay

The GLBA EPMT manages invasive species in the Dry Bay area of Glacier Bay National Preserve. Due to its relative isolation from the park's headquarters, only a single week-long visit was possible in 2011, as in previous years. There are infestations of oxeye daisy in the Dry Bay area that have been treated over the past few years. The infestation at the fish plant airstrip has been reduced in size quite significantly over that time. For hand-pulling treatments to be effective, yearly visits are necessary to keep the infestations from spreading. Due to seedling density, the oxeye daisy infestation at the Hazen cabin site near the Dog Salmon airstrip will not be eradicated for many years. In addition, the cabin site is located in an area where occasional hand-pulling efforts by park rangers stationed in Dry Bay would be difficult.

The bigleaf lupine (*L. polyphyllus*) infestations in Dry Bay are probably human introductions. However, *L. polyphyllus* is native to western North America including northern British Columbia. It is likely that this species may naturally spread its range northward into Southeast Alaska. Because of this and the lack of resources available for treatment, bigleaf lupine will no longer be treated in Dry Bay. Future decisions on its treatment will be made when it is discovered within the park boundary, which is likely since it is commonly found in Gustavus.

Aquatic plants

An aquatic plant species, *Elodea nuttallii,* was recently discovered in Fairbanks and Anchorage, Alaska in 2010 and 2011. This species has the potential to be found in Glacier Bay National Preserve due to the frequent use of the Alsek and East Alsek Rivers by charter rafting and fly fishing guide services. What may be the most threatening aspect of this species' presence is its tolerance to slightly saline waters (at least 10 ppm), of which are common in the estuary ecosystems of the preserve (MD DNR 2011). Monitoring should begin in 2012 and be ongoing for the foreseeable future due to this plant's highly invasive nature. Due to the difficulty in

accessing these areas for regular monitoring, outreach materials would be a good way to distribute information effectively so that visitors are aware of the potential threat this species poses to freshwater ecosystems and salmon infestations.

Herbicide Treatments

The perennial sowthistle infestation on Strawberry Island was partially treated with herbicide in August 2011. As a result of the success of the treatment, follow-up treatments will be performed in subsequent years as necessary.

The infestation of *P. arundinacea* on the maintenance hill will be treated in 2012 for the first time. Aquamaster, a broad spectrum glyphosate herbicide, is scheduled for use on this site. Multiple year treatments will be necessary to completely eradicate reed canarygrass from the area.

Alaska pesticide applicator licensing will likely be obtained by the GLBA EPMT biological technician in 2012 to ensure that the applications can take place as scheduled.

A consideration for the 2012 season will be to establish long-term survey sites for monitoring the chemically treated areas on Strawberry Island and the maintenance hill. A few areas of the Strawberry Island infestation were considered to be 100% cover prior to treatment, meaning nearly zero percent cover is likely next spring. A site such as this provides an opportunity to determine whether relying upon follow-up herbicide treatments is sufficient and necessary. Alternatively, it is possible that manual revegetation techniques may reduce the timeframe for native vegetation establishment and limit the need for subsequent applications in previously treated areas. A survey protocol will be developed to quantitatively monitor species diversity, percent cover, and invasive vs. native establishment over time.

Figure 14. EPMT staff Rob Fisk and Shelby Timm at the Fourth of July Festival in Gustavus.

Outreach/Education

In 2011 the GLBA EPMT staffed an outreach booth at the Gustavus Fourth of July Festival to bring awareness to invasive species present in town, the threat they pose to the native plant communities in Southeast Alaska, and what the public can do to help (Figure 14). A presentation at the Glacier Bay Lodge was given to the public regarding invasive species in Glacier Bay. A group of students from the Gustavus School came to Bartlett Cove in the fall, helped pull weeds, and learned about invasive species in the park.

Oxeye daisies should be a focus for outreach with residents of Gustavus due to the species' relative ease of identification and control. An increased public awareness of this species as well as other easily identified species such as orange hawkweed should be a priority. Oxeye daisy infestations will continue to increase unless there is an effort to control their spread. Orange hawkweed, which ranks quite high with an invasiveness ranking of 79, is present in Gustavus in only very limited numbers.

Efforts should be made to include invasive species awareness and education in the GLBA interpretive staff program development. A half-day training of interpretive staff would be a good way to get lots of information to those who are interacting with park visitors on a daily basis. Continuing to inform visitors and residents about the threats that are posed by species that have yet to show up in Gustavus but are likely in the coming years will be very critical to finding infestations before they spread.

Educating GLBA maintenance staff about the potential problems with moving contaminated soil and disturbing native vegetation will help to alleviate much of the pressure that is put on native plant communities. These actions have direct impacts on native plants and significantly increase opportunities for invasive species introduction. While these points may be addressed by the Vegetation Management Plan in the near future, it is important to educate park staff about other ways that their actions may have a detrimental effect on invasive plant control efforts. For example, improving techniques for vegetation alteration by favoring selective pruning versus mowing is a good example of small changes that can have a very positive impact in the long run.

Figure 15. A SAGA crewmember showing off a captured native crab.

Invasive Fauna

Monitoring for the European green crab (*Carcinus maenas*) was continued in 2011. Trapping was increased to three days per month to acquire more accurate datasets. No green crabs were found this season (Figure 15). European green crabs have yet to be reported north of Vancouver Island, British Colombia, Canada (ADF&G 2007). They are a nuisance invasive species that has the potential to displace native crab species and threaten shellfish and shorebird infestations (PWS RCAC 2004). Monitoring will continue in coming years to detect the presence of *Carcinus maenas* in Glacier Bay.

Non-native tunicates, soft-bodied marine invertebrates that attach to hard surfaces, have been found in Alaskan waters in recent years. The most threatening of these is *Didemnum vexillum* or *D. vex*, which was found in Sitka's Whiting Harbor in June 2010. Since its discovery, eradication efforts have been pursued, and monitoring has increased. Monitoring has been ongoing in Glacier Bay by the EPMT program and should continue. *D. vex* has the potential to seriously damage not only shoreline habitats but deeper offshore areas as well. Other potential invasive tunicate species being monitored are *Botrylloides violaceous* and *Botryllus schlosseri*, none of which were detected in Glacier Bay in 2011.

Active monitoring for Gypsy moths (*Lymantria dispar*) began in 2011 and will be repeated in 2012. Traps were deployed at locations near the airport, at the garden store in Gustavus, and at the Gustavus ferry terminal. No invasive moths were found at the three locations. Gypsy moths depend upon deciduous tree species for food and can cause serious defoliation in mid-summer, threatening the health of the affected trees and other species that depend upon them. Current established infestations have spread westward across the upper United States, currently reaching west of the Mississippi River. Disjunct infestations have been found on the west coasts of Oregon and Washington (APHIS 2011). There are European and Asian strains of the *L. dispar*;

the European strain is the most abundant in the U.S. However, a single male Asian gypsy moth was found in Fairbanks in 2006 (ADF&G 2011).

The European collared dove (*Streptopelia decaocto*) has been seen for a few years in Gustavus and Bartlett Cove, as well as in Dry Bay in Glacier Bay National Preserve. Observational reporting began in 2011 by the GLBA EPMT. While standardized data and previous years' data are not available, anecdotal information and personal communications with park staff indicate that sightings have increased from year to year. Currently, no management has been determined to be necessary due to a lack of information pointing to any detrimental effects on native species as a result of its presence. However, reporting should continue to track the spread of this species in the area to assist in future assessment and management decisions.

Other non-native species of interest with no formal active monitoring or reporting currently in GLBA include the European black slug (*Arion ater*), Atlantic salmon (*Salmo salar*), European starling (*Sturnus vulgaris*), barred owl (*Strix varia*) and brown-headed cowbird (*Molothrus ater*). Each species has a different level of interest for GLBA. In some instances, the species may have no known detrimental effect on native infestations and could be a result of a normal range expansion. Others may pose a concern for the park's ecosystems. At this time no decisions have been made regarding any immediate response to the potential presence of these species.

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